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Assessing Effective Mask Use by the Public in Two Countries: An Observational Study

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ABSTRACT

Objectives During the COVID-19 pandemic wearing a mask in public has been recommended in some settings and mandated in others. How often this advice is followed, how well, and whether it inadvertently leads to more disease transmission opportunities due to a combination of improper use and physical distancing lapses, is unknown.

Design Cross-sectional observational study performed June-August 2020.

Setting Eleven outdoor and indoor public settings (some with mandated mask use, some without) each in Toronto, Ontario, Canada and Portland, Oregon.

Participants All passersby in study settings.

Outcome Measures Mask use, incorrect mask use, and number of breaches (i.e. coming within 2 metres of someone else where both parties were not properly masked).

Results We observed 36,808 persons, the majority of whom were estimated to be age 31-65 (49%). Two-thirds (66.7%) were wearing a mask. Mandatory mask-use settings were overwhelmingly associated with mask-use (adjusted odds ratio [OR] 79.2; 95% confidence interval [CI] 47.4-135.1). Younger age, male sex, Torontonians, and public transit or airport settings (versus in a store) were associated with lower adjusted odds of wearing a mask. Fourteen percent of mask-wearers wore them incorrectly. Mandatory mask-use settings were associated with lower adjusted odds of mask error (OR 0.30; 95% CI 0.14-0.73), along with female sex and Portland subjects. Subjects aged 81+ years (versus 31-65 years), and those on public transit and at the airport (versus stores) had higher odds of mask errors. Mask-wearers had a large reduction in adjusted mean number of breaches (rate ratio [RR] 0.19; 95% CI, 0.17-0.20). The age 81+ group had the largest association with breaches (RR 7.77; 95% CI, 5.32-11.34).

Conclusions Mandatory mask use was associated with a large increase in mask-wearing. Mask-users had a large reduction in the mean number of breaches (disease transmission opportunities), despite 14% of them wearing masks incorrectly. The elderly and transit users may warrant interventions aimed at improving mask use.

Strengths and limitations of this study

- Large study (over 36,000 observations) conducted in two large North American cities of real-world use of masks by the public
- By including an assessment of physical distancing breaches, we were able to demonstrate whether the observed mask-wearing errors actually led to increased opportunities for disease transmission
- Subject characteristics had to be estimated by data collectors, and were not able to be confirmed
- Data was collected during the summer of 2020: results could differ depending on lockdown status

INTRODUCTION

Public mask-use has been recommended by national and international health authorities to slow the spread of COVID-19.[1,2] Masks have subsequently become an integral part of everyday life in countries around the world. It is hoped that vaccination will reduce or remove the need for masking in public; however, population-wide vaccination against COVID-19 is limited by a number of factors.[3,4] Following the discovery and approval of a vaccine(s), there remain challenges in scaling manufacturing and delivery systems for global access, the establishment of robust cold chain systems (if required for the vaccine platform), and facilitating access to high-risk individuals. Thus masks will continue to play an important role in COVID-19 disease control for some time.

Lab studies demonstrate that face masks, when worn appropriately, reduce respiratory droplets and aerosols for coronavirus, influenza virus, and rhinovirus.[5] The evidence that mask use by the public in community settings reduces COVID-19 transmission is limited.[6-9] An epidemiological study found that states with mandatory masking policies via state executive orders had substantial declines in the daily COVID-19 growth rate following implementation; however, actual compliance with the orders was not measured.[10] Mask-wearing by the public was rated as poor in one study,[11] but it was not conducted during a pandemic. Another study conducted in Hong Kong found that >97% of the public were wearing masks during the 3-day study period in April 2020;[12] however, it did not assess appropriate wear, and mask-use in Hong Kong may not be representative of other regions. A trial in Denmark found no reduction in COVID-19 infection between subjects assigned to the recommendation to wear masks and those who were not, but only 46% of subjects in that trial setting reported wearing a mask as recommended.[9] How frequently masks are worn in real life, in settings where they are recommended versus mandated, and how effectively members of the public wear masks, is not well-established.

Incorrect mask use during a pandemic has the potential to increase rather than decrease disease transmission.[13] In this study we examined how frequently members of the public wear a mask in multiple public venues (including during times of non-mandatory and mandatory mask use in indoor settings) in Toronto, Canada, and Portland, Oregon, United States (U.S.). We also assessed what proportion were worn incorrectly, and the number of "breaches" of physical distancing recommendations or episodes with potential for disease transmission (defined as coming within 2 metres of another person[14,15] when both parties were not wearing a mask or wearing one but incorrectly). We hypothesized that masks would give the public a false sense of security, leading to reduced physical distancing, and, along with a high rate of incorrect mask-wearing, this would result in more overall breaches among mask-wearers than among those who were not wearing a mask.

METHODS

Study Design

This prospective observational study examined mask-use by the public in multiple public locations between June and August 2020 in two large urban cities, Toronto, Ontario, Canada and Portland, Oregon, U.S. The study was approved by the Research Ethics Board of Sunnybrook Health Sciences Centre and a waiver of consent was obtained. The Oregon Health and Science University Internal Review Board considered this a non-human subjects study and waived consent.

Study Population and Setting

All persons present at any of the *a priori*-selected sites during a study shift were eligible; there were no exclusion criteria. We chose study sites based on WHO guidelines around COVID-19 spread and mask-use (i.e. outdoors has a lower risk of spread), and anticipated differences in mask-use by site.[14,15] These included (in each city) six outdoor spaces (waterfront walkways, downtown streets, suburban business streets, public squares, parks, cemeteries), three retail stores (grocery store, drugstore/pharmacy [none in Portland], hardware store), airports (Pearson International and Portland International Airport), and public transit (bus, subway, tram). Shifts were approximately 4 hours in duration, and each data collector went to at least two sites overall.

Data collection began in stores, airports, and outdoors in June, and a month later Toronto introduced a bylaw mandating mask-wearing on public transit (July 2, 2020)[16] and in indoor public settings (July 7, 2020),[17] while Pearson International Airport asked all airport patrons to mask on June 1, 2020, just prior to the start of data collection.[18] Portland introduced mandates on June 6, 2020, requiring that facemasks be worn in any situation in which physical distancing could not be maintained.[19] Therefore, all airport and all public transit study observations occurred in the setting of mandated mask-use, while the majority (but not all) of observations made in stores did.

Data Collection and Outcome Measures

A standardized data collection instrument was created in Excel (Microsoft Corp., Redmond, WA) by the first author, and circulated among the study team. After several rounds of revisions, the team met via video conference to review videos taken at several sites, to ensure inter-observer reliability among data collectors. As this was a purely observational study, without subject contact, the data collectors estimated each subject's age group (0-10, 11-30, 31-65, 66-80, 81+) and sex. The meeting was recorded and shared with the Portland team, along with the standardized data collection instrument.

Outcomes included mask use, mask error, and, because an error doesn't necessarily mean an opportunity for disease transmission, breaches. Based on the training videos, the team decided that certain sites might have such a high volume of passersby that the data collector could not accurately record both mask-use and breaches for every person present. In those high-volume situations, data collection of mask use and breaches were divided into two separate shifts, which were performed at the same time of day and day type [weekday or weekend]). During the first shift, only mask use was assessed, and, if worn, whether it was worn incorrectly and how, would be collected. During the second shift at that same site, the data collector would follow one subject at a time, recording the number breaches that occurred with other subjects, and not attempt to record every person present. The former shift would provide an overall rate of mask use and what proportion were incorrectly worn (and specific errors), and the latter would be used to determine breaches by mask group. This approach resulted in slightly different denominators for mask use and breaches.

For the purpose of our study, a mask was defined as either a surgical mask, N95 respirator, cloth mask, face shield, a face covering such as a gaiter, and a cover over a baby stroller. Incorrect mask use involved exposure of either the nares, the mouth, or both. Four types of incorrect mask use were defined *a priori*; all others were documented as "other". The definition of a breach had to have the potential for spread of COVID-19, and was based on Public Health Agency of Canada (PHAC) and Centers for Disease Control (CDC) guidelines: coming within 2 metres or 6 feet of another person,[14,15] when both parties either had no mask or a mask that was worn incorrectly (i.e. if two or more subjects came within two meters but one or both parties were wearing a mask correctly, it was not considered a breach).

Data Analysis

We used descriptive statistics to describe subject characteristics, as appropriate. To assess the variables that were independently associated with wearing a mask, we fitted a logistic regression model that included the following variables: age group, sex, accompanied (i.e. not alone), city, mandatory mask-use setting, setting type. We used the same variables in logistic regression modeling to estimate the odds of making a mask error, restricting that analysis to subjects who were wearing a mask. Lastly, to answer our study hypothesis, we fitted a Negative Binomial regression model regressing the number of breaches on the same variables. The independent variable of interest was wearing a mask.

In all regression models, we decided *a priori* to test for an interaction between age group and whether the person was accompanied, hypothesizing that young people in groups would be less likely to wear masks and more likely to make mask errors and breaches than older persons accompanied by another person or in a group. For all analyses, a p-value of 0.05 or less was considered significant. Analyses were performed with Excel and SAS (Version 9.3, SAS Institute Inc., Cary, NC).

Patient and Public Involvement

The rapid timeframes in which the research was conducted limited the scope for public involvement in study design or execution. Permission and input was obtained from privately-owned indoor settings.

RESULTS

After removal of 26 (0.07%) subjects who did not have their mask-use recorded, 36,808 individual observations remained in the cohort. There were slightly more observations made in Toronto (56.3%) than Portland (43.7%). The largest estimated age group was "adult" or age 31-65 years (48.6%), followed by 11-30 years (39.0%) (Table 1). The slight majority were estimated to be male (54.2%), and 43.9% were accompanied by someone.

Two-thirds (67.7%; 95% confidence interval [CI], 67.2-68.1) of the subjects were wearing a mask. Mask use ranged by setting type from 41.9% in outdoor spaces to 97.2% in stores. Among only settings with mandatory mask-use, mask-use ranged from 79.2% on public transit to 98.2% in stores. After adjustment, mandatory mask use was overwhelmingly associated with wearing a mask (odds ratio [OR] 79.2; 95% CI 47.4-135.1) (Figure 1). As the estimated age increased, the adjusted odds of wearing a mask did as well. Females were more likely to wear masks than males (OR 1.39; 95% CI 1.31-1.47), as were subjects in Portland compared to Toronto (OR 5.98; 95% CI 5.61-6.38). Compared to inside stores, subjects at the airport (OR 0.36; 95% CI, 0.28-0.46) and on public transit (OR 0.09; 95% CI 0.07-0.11) were less likely to wear a mask, as were subjects who were accompanied by someone else (OR 0.73; 95% CI 0.70-0.78). The interaction variable for age group and accompanied was not significant (p=0.07).

Of the 24,911 subjects wearing a mask, 3,384 (13.6%; 95% CI, 13.2-14.0) wore their mask incorrectly (Table 1). The percentage of subjects wearing a mask incorrectly varied across setting type: from 7.9% in mandatory mask-use stores to 20.0% outdoors (Figure 2). In mandatory mask-use settings, the proportion of people wearing it incorrectly ranged from 7.9% in stores to 17.5% on public transit. In the adjusted analyses, the variable with the largest effect size on wearing a mask incorrectly was mandatory mask use (OR 0.30; 95% CI 0.14-0.73) (Figure 3). Compared to the adult age group, only the 11-30 years and eldest (81+ years) groups were associated with making a mask error (less likely and more likely, respectively). Females were less likely than males to make a mask-wearing error (OR 0.78; 95% CI 0.72-0.84), as were Portland subjects compared to those in Toronto (OR 0.46; 95% CI 0.42-0.50. The airport (OR 1.70; 95% CI 1.50-1.95) and transit (OR 2.36; 95% CI 2.03-2.74) settings were both associated with more mask-wearing errors compared to in stores. The interaction between age and being accompanied was not significant (p=0.07).

Among subjects observed to make a mask-wearing error, the most common documented error was the “chin-strap”, where both the nares and mouth were exposed (53.9%) (Table 1). The next most frequent error was exposure of the nares (34.4%), followed by pulling the mask down to speak (4.4%). By setting, the “chin-strap” error constituted the large majority of incorrect wear in outdoor spaces (74.1%; 95% CI, 71.9-76.2), and the slight majority on public transit (48.5%; 95% CI, 44.1-53.0) (Figure 2). Wearing the mask with solely the nares exposed was the predominant mask error made in stores (74.0%) and airports (45.8%). Combining all settings with mandatory mask use, the predominant mask-wearing error was having solely the nares exposed (50.2%; 95% CI, 47.9-52.5).

Overall, 9,021 breaches were observed, for a rate of 26 breaches per 100 persons observed (Figure 4). The number of breaches was much higher in the non-mask wearing group (66/100 persons observed) compared to the group wearing a mask (including those wearing it correctly and not) (7/100 persons observed). This relationship was maintained across all settings. Specifically, while the rate of breaches was very high in the group who wore a mask *but wore it incorrectly* (55/100 persons observed), once included with the other mask-wearing subjects (i.e. those who wore it correctly), the overall number of breaches among the mask-wearing group was far below that of the non-mask wearing group. The adjusted rate ratio of a breach if wearing a mask compared to not wearing one was 0.19 (95% CI, 0.17-0.20) (Figure 5). Other variables independently associated with the number of breaches, in order of declining effect size, included being in the elderly (> 80 years) age group (RR 7.77; 95% CI, 5.32-11.34) vs the adult group, being on transit (RR 3.22; 95% CI, 2.68-3.88) vs in a store, mandatory mask use (RR 0.50; 95% CI, 0.28-0.87), age 66-80 years (RR 1.32; 95% CI, 1.16-1.50) vs adult, and being with someone else (RR 1.18; 95% CI 1.10-1.26). Portland subjects (RR 0.93; 95% CI, 0.87-1.00) vs Toronto had a borderline association. The interaction term in the breaches model was not significant ($p = 0.0523$). Thus, in contrast to our *a priori* hypothesis that younger persons who were with someone would be more likely to have breaches than older accompanied persons, the younger adult group was not associated with an increased number of breaches.

DISCUSSION

With the majority of the world's inhabitants under advisement to wear masks in public places to prevent the spread of COVID-19, it is imperative to know how often this advice is being followed, how well it is being executed, and the resulting number of opportunities for disease transmission. In this study of over 35,000 observations in two large North American cities, we found that two-thirds of inhabitants wore a mask in public. This is similar to a study in Chittenden County, Vermont, which found that 75.5% of the 1004 persons observed following the lifting of lockdown in May 2020 wore a mask.[20] Consistent with that study, we found that females and older persons had higher adjusted odds of masking. Another U.S. study found that the daily COVID-19 growth rate fell following the institution of state-wide mandates to wear masks,[10] and our study demonstrates that mandating mask use in public spaces is strongly associated with compliant mask-wear by the public. Taken together, it suggests that mask-use mandates are effective at improving mask-wearing and limiting COVID-19 spread.

Appropriately, we found that the proportion of mask-wearing was lower in outdoor spaces (42%), consistent with guidelines and lower risk of transmission,[21,22] and very high (>95%) in indoor public spaces with mandatory mask-wearing rules, such as stores and airports. Less appropriately, the proportion wearing a mask on public transit (which was mandatory for the duration of the study) fell between the two, at 79%. Unfortunately, 18% of the latter group were also wearing their mask incorrectly, as were 20% of the subjects who wore a mask outdoors and 11% of those in mandatory mask-use settings. These findings suggest that initiatives on how to wear a mask properly, and reminders in certain public spaces, may be needed.

It is possible that "judicious" incorrect mask-wearing, or wearing a mask incorrectly when farther than 2 metres from anyone else but positioning it properly if coming within 2 metres of another person, may be occurring. We hypothesized that incorrect mask use with the "chin strap", which was most popular in spacious outdoor settings, might be a purposeful choice. In comparison, we hypothesized that the nares exposed might be an inadvertent error (perhaps the top band was not 'pinched' properly, or the mask was too big or worn upside down, or the straps were too long). However, many of the subjects observed to be wearing their mask as a "chin-strap" subsequently had a breach (among outdoor subjects, 63 breaches/100 persons observed). These findings suggest that if done purposefully, "judicious" incorrect mask-wearing doesn't work particularly well.

Despite the high number of breaches among people who wear their mask incorrectly, the high proportion of mask-wearers who wore their mask correctly (and were subsequently unable to breach) diluted the overall number of breaches to a much lower level in the mask-wearing group relative to the non-mask-wearing group. This is contrary to our *a priori* hypothesis, with similar results after adjustment for potential confounders. Of note, in addition to much higher adjusted odds of making a mask-wearing error, the elderly also had a very high adjusted rate of breaches relative to younger persons, which could be secondary to a false sense of security when wearing a mask. The high rate of breaches is particularly worrisome given that they are the highest risk age group.[23,24] This suggests that future interventions that target this group are urgently needed.

Limitations of our study include the setting of two large North American cities; our results may not apply to more suburban or rural areas. In order to include a large and representative sample of the public, as well as avoid the bias introduced by the consent process, we did not consent subjects, and in turn, we had to estimate their characteristics rather than collect this information. Despite our large numbers, the sample size of the elderly age group was small, likely due to the advisory for this group to stay at home. Certain mask-wearing errors were momentary, and if there was uncertainty, we gave subjects the benefit of the doubt and did not count it as an error; for example, a subject who boarded a bus without a mask, but immediately took a mask from the provided dispenser (and put it on correctly) was not counted as an error. Similarly, we did not count pulling the mask down to eat as a mask error, given that human beings need to eat, and cannot do so wearing a mask correctly. This may have resulted in a slightly conservative estimate of mask-wearing errors. It is possible that the same subject was observed twice, if they returned to the same location during a shift, or even another location that was a study site. We believe this to be rare. Lastly, public compliance with mask-wearing likely varies over time, in relation to the number of COVID-19 cases. If cases drop to near zero, our results may not apply.

CONCLUSIONS

Compliance with recommendations to wear a mask was relatively high in two large North American cities in the summer months of 2020. It was far from perfect, however, particularly on public transit. Elderly persons are the most likely to make mask-wearing errors. A mandatory requirement to wear a mask was the greatest predictor of both mask-wearing and correct wear, and was not associated with an inadvertent increase in breaches. These results support mandating mask-use in public settings as an effective strategy to prevent the spread of COVID-19.

Competing Interests: Dr Atzema had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors declare that they have no conflicts of interests.

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Contributorship Statement:

Study concept and design: Atzema, Mostarac, Javidan, Wintraub, Li, Patel, Lee, Latham N, Latham E, Button, Kea.

Acquisition of data: Mostarac, Javidan, Wintraub, Li, Patel, Lee, Latham N, Latham E, Button, Nguyen, Colbert, Chang, Chen, Buerk, Funari, Zimmerman, Somogyi, Brown.

Analysis and interpretation of data: All.

Drafting of the manuscript: Atzema.

Critical revision of the manuscript for important intellectual content: All.

Statistical Analysis: Atzema, Mostarac, Button, Kea.

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Table 1. Study cohort, overall and by study setting type

		All n=36808	Outdoor Spaces n=18336	Public Transit n=3633	Retail Stores n=4636	Airport n=10203	Mandatory Mask Use n=18394
Age	**0–10 y**	1329 (3.6)	811 (4.4)	64 (1.8)	95 (2.1)	359 (3.5)	518 (2.8)
	11–30 y	14350 (39.0)	9073 (49.5)	1759 (48.4)	928 (20.0)	2590 (25.4)	5263 (28.6)
	31–65 y	17898 (48.6)	7296 (39.8)	1600 (44.0)	2725 (58.8)	6277 (61.5)	10567 (57.4)
	66–80 y	3082 (8.4)	1127 (6.2)	205 (5.6)	803 (17.3)	947 (9.3)	1935 (10.5)
	80+ y	149 (0.4)	29 (0.2)	5 (0.1)	85 (1.8)	30 (0.3)	111 (0.6)
Sex	**Female**	16780 (45.6)	8391 (45.8)	1740 (47.9)	1960 (42.3)	4689 (46.1)	8360 (45.5)
	Male	19836 (53.9)	9814 (53.9)	1880 (51.9)	2667 (57.6)	5475 (53.9)	9973 (54.2)
	Unknown	192 (0.5)	131 (0.7)	13 (0.4)	9 (0.2)	39 (0.4)	61 (0.3)
Not alone		16139 (43.9)*25	10162 (55.5)*20	923 (25.4)*2	1135 (24.5)*2	3919 (38.4)*1	5951 (32.4)*5
Mask worn		24909 (67.7)	7690 (41.9)	2877 (79.2)	4505 (97.2)	9835 (96.4)	17190 (93.5)
Worn incorrectly		3365 (13.5)	1531 (20.0)	490 (17.0)	360 (8.0)	984 (10.0)	1826 (10.6)
Mask Errors, in Mask Wearers							
Total†		3470 (13.9)	1591 (20.7)	503 (17.5)	366 (8.1)	1010 (10.3)	1871 (10.9)
Nares exposed		1194 (34.4)	251 (15.8)	209 (41.6)	271 (74.0)	463 (45.8)	940 (50.2)
Chin-Strap‡		1871 (53.9)	1179 (74.1)	244 (48.5)	50 (13.7)	398 (39.4)	690 (36.9)
Uni-Earring$^{\lambda}$		120 (3.5)	75 (4.7)	12 (2.4)	8 (2.2)	25 (2.5)	45 (2.4)
Exposed nares & mouth to speak		154 (4.4)	35 (2.2)	13 (2.6)	22 (6.0)	84 (8.3)	116 (6.2)
Other		131 (3.8)	51 (3.2)	25 (5.0)	15 (4.1)	40 (4.0)	80 (4.3)

* number of missing datapoints
† each subject can make more than one error
‡ nares & mouth exposed
λ hanging from 1 ear

Figure Legend

Figure 1. The adjusted odds of wearing a mask*

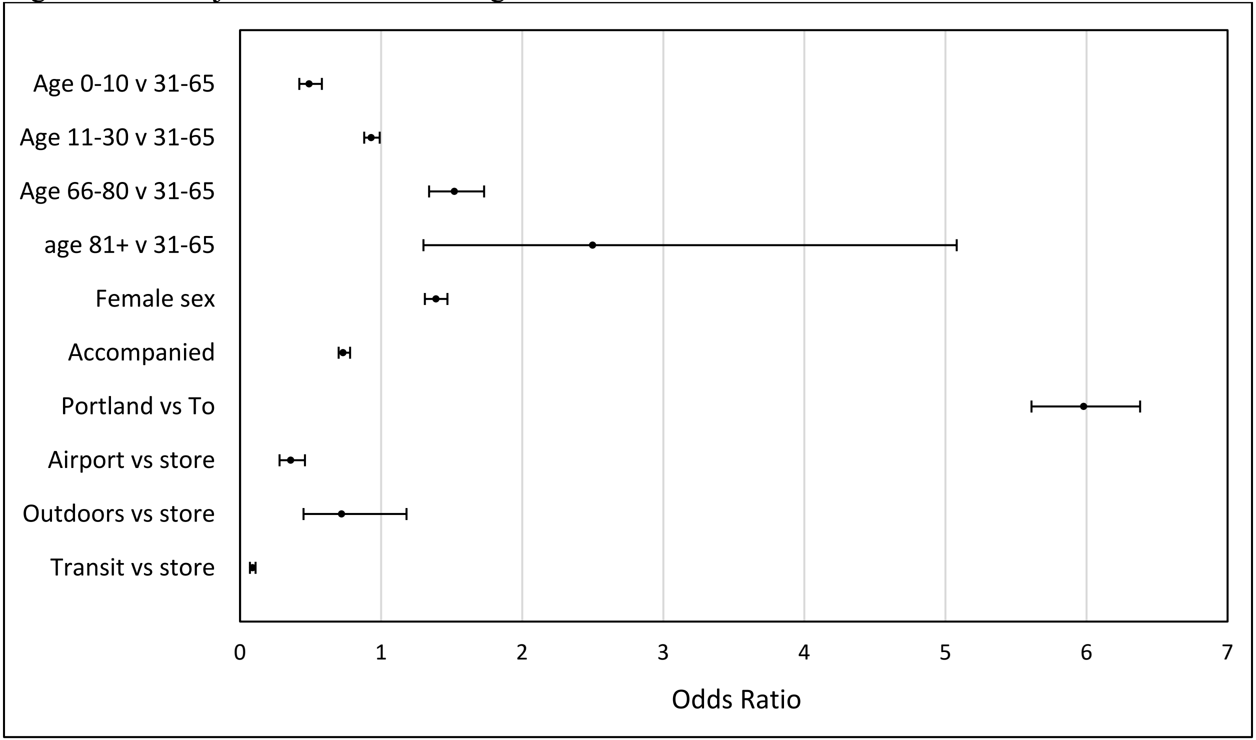
Figure 2. Masked subjects who exhibited incorrect mask-wearing practices by setting (top), and types of errors by setting (bottom)

Figure 3. Among subjects wearing a mask, the adjusted odds of wearing a mask incorrectly

Figure 4. Breaches by venue type (top) and by masking (note that the Mask worn but incorrectly group is a subset of the Mask worn group)

Figure 5. Adjusted rate ratios for breaches

Figure 1. The adjusted odds of wearing a mask*



*Mandatory mask use setting OR is not plotted to improve graph readability: OR 79.2; 95% CI, 47.4-135.
Interaction between age group and accompanied was not significant (p=0.07)

Figure 2. Masked subjects who exhibited incorrect mask-wearing practices by setting (top), and types of errors by setting (bottom)

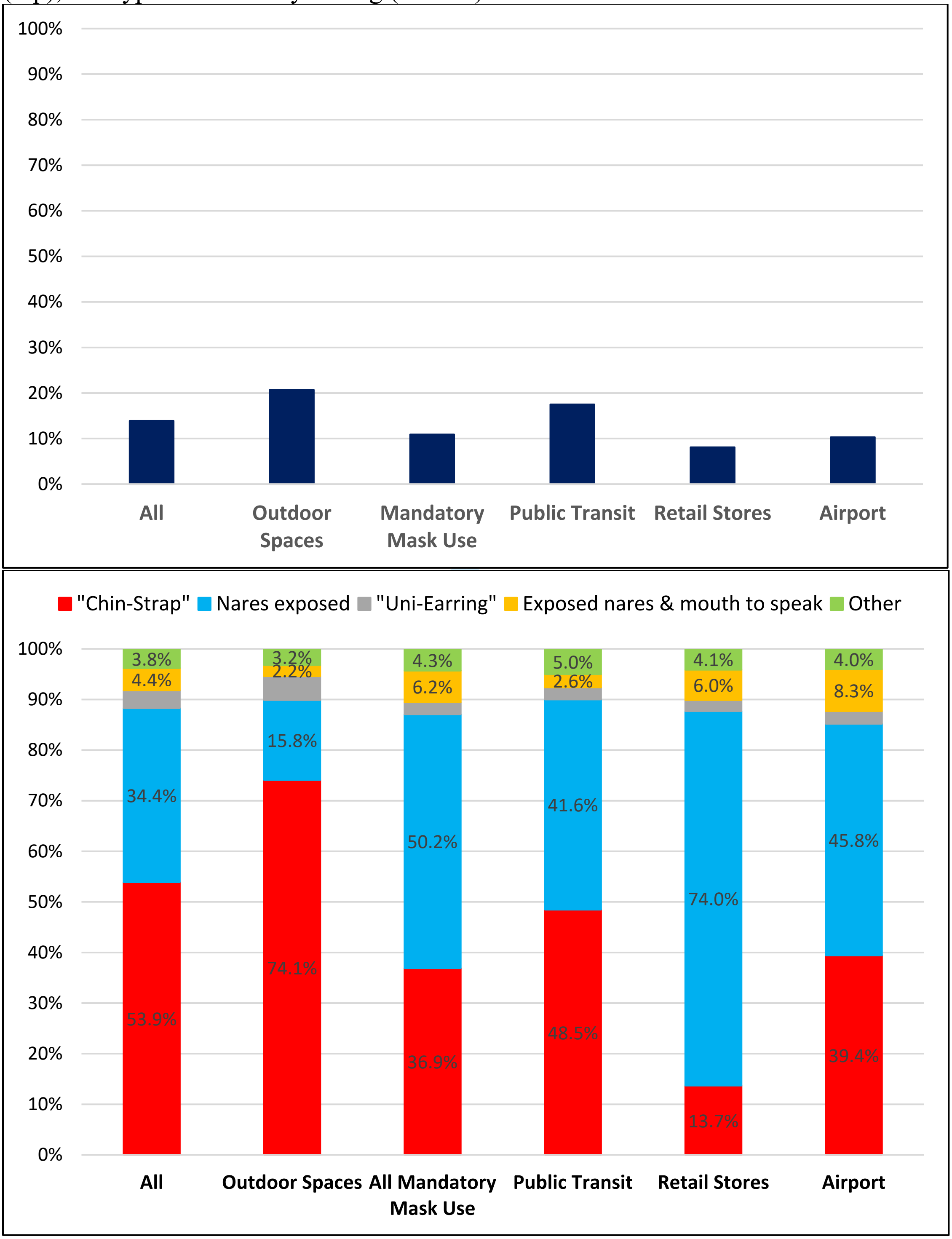
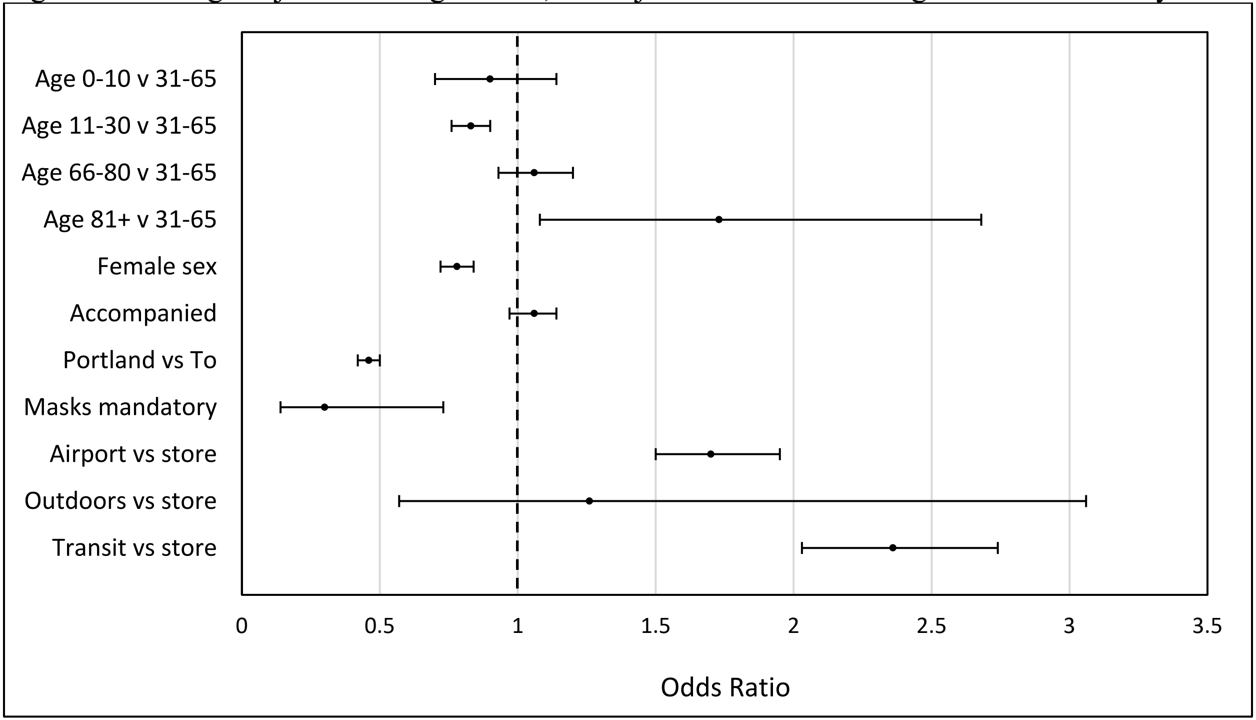
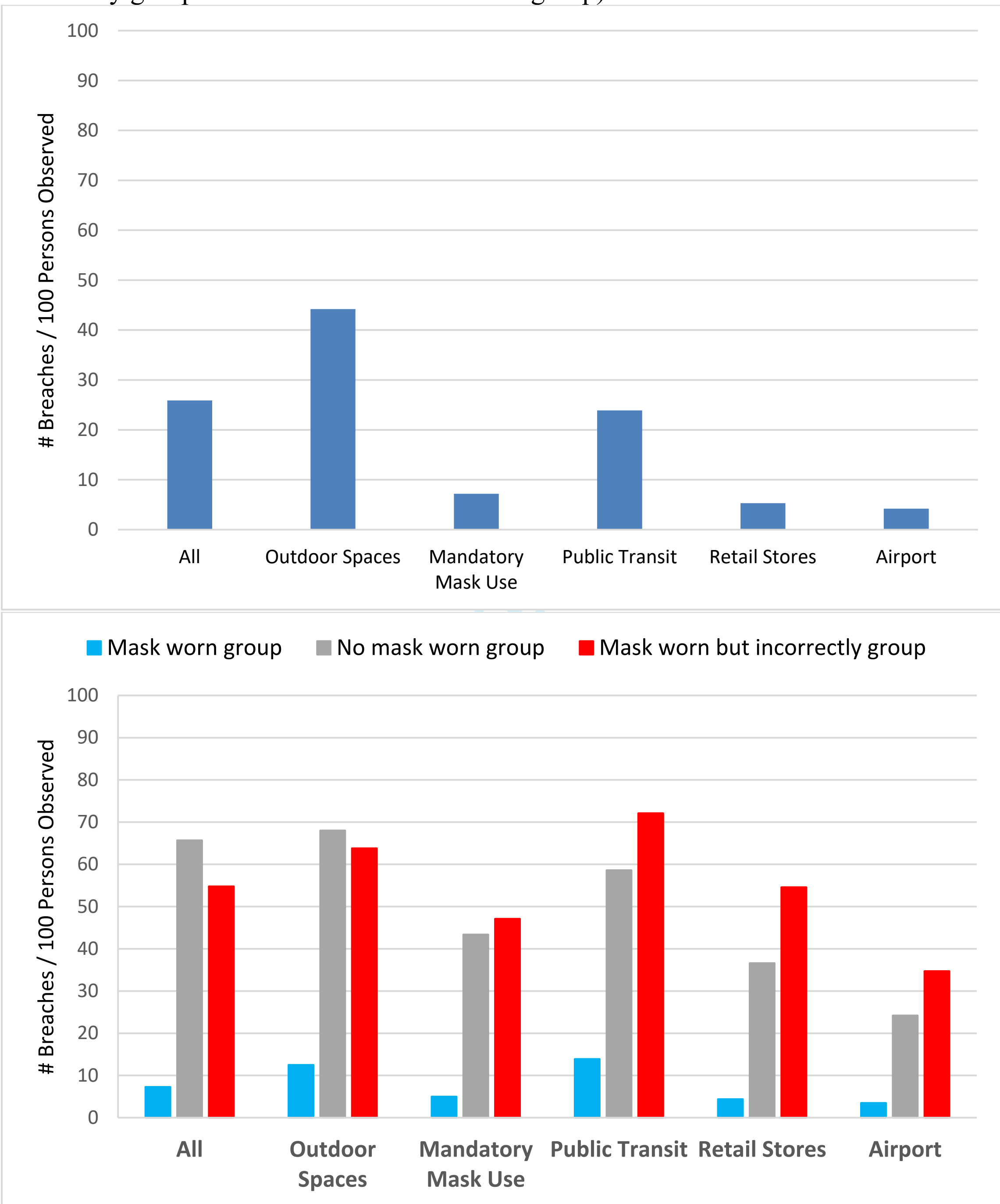


Figure 3. Among subjects wearing a mask, the adjusted odds of wearing a mask incorrectly



Interaction term for age group and accompanied was not significant (p=0.07)

Figure 4. Breaches by venue type (top) and by masking (note that the Mask worn but incorrectly group is a subset of the Mask worn group)



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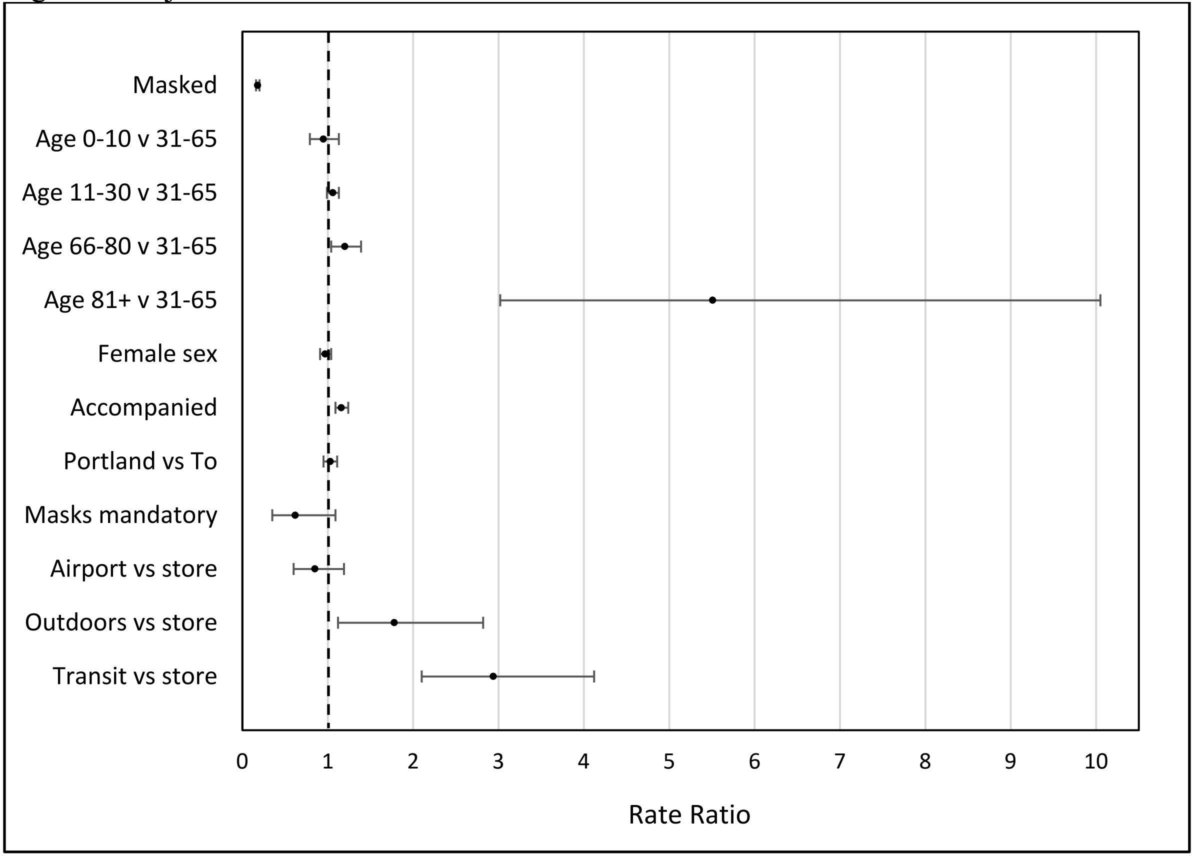

interaction term for age group and accompanied was not significant (p=0.39)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	0
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, 18
		(b) Indicate number of participants with missing data for each variable of interest	18
Outcome data	15*	Report numbers of outcome events or summary measures	9, 10, 11, 18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9, 10, 11, 19, 21, 23
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9, 10, 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11, 12, 13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	0

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Assessing Effective Mask Use by the Public in Two Countries: An Observational Study

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Text Word Count: 3456; Abstract Word Count: 312; Tables: 1; Figures: 5
Subtitle: Mask Use by the Public
Key Words: masks, public, physical distancing, social distancing, COVID-19, viral transmission, pandemic

ABSTRACT

Objectives During the COVID-19 pandemic wearing a mask in public has been recommended in some settings and mandated in others. How often this advice is followed, how well, and whether it inadvertently leads to more disease transmission opportunities due to a combination of improper use and physical distancing lapses, is unknown.

Design Cross-sectional observational study performed June-August 2020.

Setting Eleven outdoor and indoor public settings (some with mandated mask use, some without) each in Toronto, Ontario and Portland, Oregon.

Participants All passersby in study settings.

Outcome Measures Mask use, incorrect mask use, and number of breaches (i.e. coming within 2 metres of someone else where both parties were not properly masked).

Results We observed 36,808 persons, the majority of whom were estimated to be age 31-65 (49%). Two-thirds (66.7%) were wearing a mask, and 14% of mask-wearers wore them incorrectly. Mandatory mask-use settings were overwhelmingly associated with mask-use (adjusted odds ratio [OR] 79.2; 95% confidence interval [CI] 47.4-135.1). Younger age, male sex, Torontonians, and public transit or airport settings (versus in a store) were associated with lower adjusted odds of wearing a mask. Mandatory mask-use settings were associated with lower adjusted odds of mask error (OR 0.30; 95% CI 0.14-0.73), along with female sex and Portland subjects. Subjects aged 81+ years (versus 31-65 years), and those on public transit and at the airport (versus stores) had higher odds of mask errors. Mask-wearers had a large reduction in adjusted mean number of breaches (rate ratio [RR] 0.19; 95% CI, 0.17-0.20). The age 81+ group had the largest association with breaches (RR 7.77; 95% CI, 5.32-11.34).

Conclusions Mandatory mask use was associated with a large increase in mask-wearing. Despite 14% of them wearing their masks incorrectly, mask-users had a large reduction in the mean number of breaches (disease transmission opportunities). The elderly and transit users may warrant public health interventions aimed at improving mask use.

Strengths and limitations of this study

- Large study (over 36,000 observations) conducted in two large North American cities of real-world use of masks by the public
- By including an assessment of physical distancing breaches, we were able to demonstrate whether the observed mask-wearing errors actually led to increased opportunities for disease transmission
- Subject characteristics had to be estimated by data collectors, and were unable to be confirmed
- Data was collected during the summer of 2020: results could differ depending on lockdown status

INTRODUCTION

Public mask-use was recommended in spring 2020 by national and international health authorities in order to slow the spread of COVID-19.[1,2] Masks have subsequently become an integral part of everyday life in countries around the world. It is hoped that vaccination will reduce or remove the need for masking in public; however, population-wide vaccination against COVID-19 is limited by a number of factors.[3,4] Following the discovery and approval of vaccines, there remain challenges in scaling manufacturing and delivery systems for global access, as well as vaccine hesitancy. Thus masks will continue to play an important role in COVID-19 disease control for an unmeasured period.

Lab studies demonstrate that face masks, when worn appropriately, reduce respiratory droplets and aerosols for coronavirus, influenza virus, and rhinovirus.[5] The evidence that mask use by the public in community settings reduces COVID-19 transmission is limited.[6-9] An epidemiological study found that states with mandatory masking policies via state executive orders had substantial declines in the daily COVID-19 growth rate following implementation; however, actual compliance with the orders was not measured.[10] Mask-wearing by the public was rated as poor in one study,[11] but it was not conducted during a pandemic. Another study conducted in Hong Kong found that >97% of the public were wearing masks during the 3-day study period in April 2020;[12] however, it did not assess appropriate wear, and mask-use in Hong Kong may not be representative of other regions. A trial in Denmark found no reduction in COVID-19 infection between subjects assigned to the recommendation to wear masks and those who were not, but only 46% of subjects in that trial setting reported wearing a mask as recommended.[9] How frequently masks are worn in real life, in settings where they are recommended versus mandated, and how effectively members of the public wear masks, is not well-established.

Incorrect mask use during a pandemic has the potential to increase rather than decrease disease transmission.[13] In this study we examined how frequently members of the public wear a mask in multiple public venues (including during times of non-mandatory and mandatory mask use in indoor settings) in Toronto, Canada, and Portland, Oregon, United States (U.S.). We also assessed what proportion were worn incorrectly, and the number of "breaches" of physical distancing recommendations or episodes with potential for disease transmission (defined as coming within 2 metres of another person[14,15] when both parties were not wearing a mask or wearing one but incorrectly). We hypothesized that masks would give the public a false sense of security, leading to reduced physical distancing, and, along with a high rate of incorrect mask-wearing, this would result in more overall breaches among mask-wearers than among those who were not wearing a mask.

METHODS

Study Design

This prospective observational study examined mask-use by the public in multiple public locations between June and August 2020 in two urban cities, Toronto, Ontario, Canada and Portland, Oregon, U.S (see appendix 1 for demographic information). The study was approved by the Research Ethics Board of Sunnybrook Health Sciences Centre and a waiver of consent was obtained. The Oregon Health and Science University Internal Review Board considered this a non-human subjects study and waived consent.

Study Population and Setting

All persons present at any of the study sites during a study shift were eligible; there were no exclusion criteria. Study sites were chosen *a priori* by the group via consensus, based on WHO guidelines on COVID-19 spread and mask-use (i.e. outdoors has a lower risk of spread) and anticipated differences in mask-use by site.[14,15] These included (in each city) six outdoor spaces (waterfront walkways, downtown streets, suburban business streets, public squares, parks, cemeteries), three retail stores (grocery store, drugstore/pharmacy [none in Portland], hardware store), airports (Pearson International and Portland International Airport), and public transit (bus, subway, tram). Shifts were ~4 hours long, and were performed during non-nighttime hours (when there would be subjects present in stores, and enough elsewhere to be at risk of breaches), between 08:00 and 21:00. Each data collector was encouraged to divide their shifts evenly across those hours, and each attended at least two sites overall.

Data collection began in stores, airports, and outdoors in June, and a month later Toronto introduced a bylaw mandating mask-wearing on public transit (July 2, 2020)[16] and in all indoor public settings (July 7, 2020),[17] while Pearson International Airport asked all airport patrons to mask on June 1, 2020 (i.e. just prior to the start of data collection).[18] Portland introduced mandates on June 6, 2020, requiring that facemasks be worn in any situation in which physical distancing could not be maintained.[19] Therefore, all airport and all public transit study observations occurred in the setting of mandated mask-use, while the majority (but not all) of observations made in stores did.

Data Collection and Outcome Measures

A standardized data collection instrument was created in Excel (Microsoft Corp., Redmond, WA) by the first author, and circulated among the study team. After several rounds of revisions, the Toronto team underwent a collective, standardized training process. The team met via recorded video conference to review ~30 minutes of video taken at several sites; this was conducted to minimize subjectivity that may exist in interpreting the selected metrics (e.g., correct mask usage, adherence to physical distancing policies). Team members collectively reviewed each data point in the videos and discussed any discrepancies in interpretation or data collection as they occurred. In addition, the study team texted each other live from the sites during data collection in order to address any uncertainties that arose around definitions via consensus; this further ensured high inter-observer reliability. As this was a purely observational study, without subject contact, the data collectors estimated each subject's age group (0-10, 11-30, 31-65, 66-80, 81+) and sex. The recorded meeting was shared with the Portland team for their training session, along with the standardized data collection instrument; any discrepancies or questions were reviewed through collective discussion. Lastly, one member each of the Portland and Toronto teams viewed more (previously unseen) video footage taken in Toronto of 92 subjects, to determine interrater reliability using Cohen's kappa: wearing a mask 0.96, incorrect mask use 1.0.

Outcomes included mask use, mask error, and, because an error doesn't necessarily mean an opportunity for disease transmission, breaches. Based on the training videos, the team decided that certain sites might have such a high volume of passersby that the data collector could not accurately record both mask-use and breaches for every person present. In those high-volume situations, data collection of mask use and breaches were divided into two separate shifts, which were performed at the same time of day and day type [weekday or weekend]). During the first shift, only mask use was assessed, and, if worn, whether it was worn incorrectly and how. During the second shift at that same site, the data collector would follow one subject at a time, recording the number breaches that occurred with other subjects, and not attempt to record every person present. The former shift would provide an overall rate of mask use and what proportion were incorrectly worn (and specific errors), and the latter would be used to determine breaches by mask group. This approach resulted in slightly different denominators for mask use and breaches.

For the purpose of our study, consistent with guidelines issued at the time of the study from both countries,[1,2] a mask was defined as either a surgical mask, N95 respirator, cloth mask, a gaiter, and a cover over a baby stroller. A face shield worn *without* a mask was considered 'no mask'. Incorrect mask use involved a mask with exposure of either the nares, the mouth, or both. Four specific types of incorrect mask use were defined *a priori*; all others were documented as "other". The definition of a breach had to have the potential for spread of COVID-19, and was based on Public Health Agency of Canada and Centers for Disease Control guidelines: coming within 2 metres or 6 feet of another person,[14,15] when both parties either had no mask or a mask that was worn incorrectly (i.e. if two or more subjects came within two meters but one or both parties were wearing a mask correctly, it was not considered a breach).

Data Analysis

We used descriptive statistics to describe subject characteristics, as appropriate. To assess the variables that were independently associated with wearing a mask, we fitted a logistic regression model that included the following variables: age group, sex, accompanied (i.e. not alone), city, mandatory mask-use setting, setting type. We used the same variables in logistic regression modeling to estimate the odds of making a mask error, restricting that analysis to subjects who were wearing a mask. Lastly, to answer our study hypothesis, we fitted a Negative Binomial regression model regressing the number of breaches on the same variables. The independent variable of interest was wearing a mask.

In all regression models, we decided *a priori* to test for an interaction between age group and whether the person was accompanied, hypothesizing that young people in groups would be less likely to wear masks and more likely to make mask errors and breaches than older persons accompanied by another person or in a group. For all analyses, a p-value of 0.05 or less was considered significant. Analyses were performed with Excel and SAS (Version 9.3, SAS Institute Inc., Cary, NC).

Patient and Public Involvement

The rapid timeframes in which the research was conducted limited the scope for public involvement in study design or execution. Permission and input was obtained from privately-owned indoor settings.

RESULTS

After removal of 26 (0.07%) subjects who did not have their mask-use recorded, 36,808 individual observations remained in this cross-sectional study. There were slightly more observations made in Toronto (56.3%) than Portland (43.7%). The largest estimated age group was "adult" or age 31-65 years (48.6%), followed by 11-30 years (39.0%) (Table 1). The slight majority were estimated to be male (54.2%), and 43.9% were accompanied by someone.

Table 1. Study cohort, overall and by study setting type

		All	Outdoor Spaces	Public Transit	Retail Stores	Airport	Mandatory Mask Use
		n=36808	n=18336	n=3633	n=4636	n=10203	n=18394
Age	**0–10 y**	1329 (3.6)	811 (4.4)	64 (1.8)	95 (2.1)	359 (3.5)	518 (2.8)
	11–30 y	14350 (39.0)	9073 (49.5)	1759 (48.4)	928 (20.0)	2590 (25.4)	5263 (28.6)
	31–65 y	17898 (48.6)	7296 (39.8)	1600 (44.0)	2725 (58.8)	6277 (61.5)	10567 (57.4)
	66–80 y	3082 (8.4)	1127 (6.2)	205 (5.6)	803 (17.3)	947 (9.3)	1935 (10.5)
	80+ y	149 (0.4)	29 (0.2)	5 (0.1)	85 (1.8)	30 (0.3)	111 (0.6)
Sex	**Female**	16780 (45.6)	8391 (45.8)	1740 (47.9)	1960 (42.3)	4689 (46.1)	8360 (45.5)
	Male	19836 (53.9)	9814 (53.9)	1880 (51.9)	2667 (57.6)	5475 (53.9)	9973 (54.2)
	Unknown	192 (0.5)	131 (0.7)	13 (0.4)	9 (0.2)	39 (0.4)	61 (0.3)
Not alone		16139 (43.9)*[25]	10162 (55.5)*[20]	923 (25.4)*[2]	1135 (24.5)*[2]	3919 (38.4)*[1]	5951 (32.4)*[5]
Mask worn		24909 (67.7)	7690 (41.9)	2877 (79.2)	4505 (97.2)	9835 (96.4)	17190 (93.5)
Worn incorrectly		3365 (13.5)	1531 (20.0)	490 (17.0)	360 (8.0)	984 (10.0)	1826 (10.6)
Mask Errors, in Mask Wearers							
Total†		3470 (13.9)	1591 (20.7)	503 (17.5)	366 (8.1)	1010 (10.3)	1871 (10.9)
Nares exposed		1194 (34.4)	251 (15.8)	209 (41.6)	271 (74.0)	463 (45.8)	940 (50.2)
Chin-Strap‡		1871 (53.9)	1179 (74.1)	244 (48.5)	50 (13.7)	398 (39.4)	690 (36.9)
Uni-Earring[λ]		120 (3.5)	75 (4.7)	12 (2.4)	8 (2.2)	25 (2.5)	45 (2.4)
Exposed nares & mouth to speak		154 (4.4)	35 (2.2)	13 (2.6)	22 (6.0)	84 (8.3)	116 (6.2)

Other	131 (3.8)	51 (3.2)	25 (5.0)	15 (4.1)	40 (4.0)	80 (4.3)

* number of missing datapoints
† each subject can make more than one error
‡ nares & mouth exposed
λ hanging from 1 ear

Two-thirds (67.7%; 95% confidence interval [CI], 67.2-68.1) of the subjects were wearing a mask. Mask use ranged by setting type from 41.9% in outdoor spaces to 97.2% in stores. Among only settings with mandatory mask-use, mask-use ranged from 79.2% on public transit to 98.2% in stores. After adjustment, mandatory mask use was overwhelmingly associated with wearing a mask (odds ratio [OR] 79.2; 95% CI 47.4-135.1) (Figure 1). As the estimated age increased, the adjusted odds of wearing a mask did as well. Females were more likely to wear masks than males (OR 1.39; 95% CI 1.31-1.47), as were subjects in Portland compared to Toronto (OR 5.98; 95% CI 5.61-6.38). Compared to inside stores, subjects at the airport (OR 0.36; 95% CI, 0.28-0.46) and on public transit (OR 0.09; 95% CI 0.07-0.11) were less likely to wear a mask, as were subjects who were accompanied by someone else (OR 0.73; 95% CI 0.70-0.78). The interaction variable for age group and accompanied was not significant (p=0.07).

Of the 24,911 subjects wearing a mask, 3,384 (13.6%; 95% CI, 13.2-14.0) wore their mask incorrectly (Table 1). The percentage of subjects wearing a mask incorrectly varied across setting type: from 7.9% in mandatory mask-use stores to 20.0% outdoors (Figure 2). In mandatory mask-use settings, the proportion of people wearing it incorrectly ranged from 7.9% in stores to 17.5% on public transit. In the adjusted analyses, the variable with the largest effect size on wearing a mask incorrectly was mandatory mask use (OR 0.30;

95% CI 0.14-0.73) (Figure 3). Compared to the adult age group, only the 11-30 years and eldest (81+ years) groups were associated with making a mask error (less likely and more likely, respectively). Females were less likely than males to make a mask-wearing error (OR 0.78; 95% CI 0.72-0.84), as were Portland subjects compared to those in Toronto (OR 0.46; 95% CI 0.42-0.50. The airport (OR 1.70; 95% CI 1.50-1.95) and transit (OR 2.36; 95% CI 2.03-2.74) settings were both associated with more mask-wearing errors compared to in stores. The interaction between age and being accompanied was not significant (p=0.07).

Among subjects observed to make a mask-wearing error, the most common documented error was the “chin-strap”, where both the nares and mouth were exposed (53.9%) (Table 1). The next most frequent error was exposure of the nares (34.4%), followed by pulling the mask down to speak (4.4%). By setting, the “chin-strap” error constituted the large majority of incorrect wear in outdoor spaces (74.1%; 95% CI, 71.9-76.2), and the slight majority on public transit (48.5%; 95% CI, 44.1-53.0) (Figure 2). Wearing the mask with solely the nares exposed was the predominant mask error made in stores (74.0%) and airports (45.8%). Combining all settings with mandatory mask use, the predominant mask-wearing error was having solely the nares exposed (50.2%; 95% CI, 47.9-52.5).

Overall, 9,021 breaches were observed, for a rate of 26 breaches per 100 persons observed (Figure 4). The number of breaches was much higher in the non-mask wearing group (66/100 persons observed) compared to the group wearing a mask (including those wearing it correctly and not) (7/100 persons observed). This relationship was maintained across all settings. Specifically, while the rate of breaches was very high in the group who wore a mask *but wore it* *incorrectly* (55/100 persons observed), once included with the other mask-wearing subjects (i.e. those who wore it correctly), the overall number of breaches among the mask-wearing group was far below that of the non-mask wearing group. The adjusted rate ratio of a breach if wearing a mask compared to not wearing one was 0.19 (95% CI, 0.17-0.20) (Figure 5). Other variables independently associated with the number of breaches, in order of declining effect size, included being in the elderly (> 80 years) age group (RR 7.77; 95% CI, 5.32-11.34) vs the adult group, being on transit (RR 3.22; 95% CI, 2.68-3.88) vs in a store, mandatory mask use (RR 0.50; 95% CI, 0.28-0.87), age 66-80 years (RR 1.32; 95% CI, 1.16-1.50) vs adult, and being with someone else (RR 1.18; 95% CI 1.10-1.26). Portland subjects (RR 0.93; 95% CI, 0.87-1.00) vs Toronto had a borderline association. The interaction term in the breaches model was not significant (p = 0.0523). Thus, in contrast to our *a priori* hypothesis that younger persons who were with someone would be more likely to have breaches than older accompanied persons, the younger adult group was not associated with an increased number of breaches.

DISCUSSION

With the majority of the world's inhabitants under advisement to wear masks in public places to prevent the spread of COVID-19, it is imperative to know how often this advice is being followed, how well it is being executed, and the resulting number of opportunities for disease transmission. In this study of over 35,000 observations in two urban North American cities, we found that two-thirds of inhabitants wore a mask in public. This is similar to a study in Chittenden County, Vermont, which found that 75.5% of the 1004 persons observed following the lifting of lockdown in May 2020 wore a mask.[20] Consistent with that study, we found that females and older persons had higher adjusted odds of masking. Another U.S. study found that the daily COVID-19 growth rate fell following the institution of state-wide mandates to wear masks,[10] and our study demonstrates that mandating mask use in public spaces is strongly associated with compliant mask-wear by the public. Taken together, it suggests that mask-use mandates are effective at improving mask-wearing and limiting COVID-19 spread.

Appropriately, we found that the proportion of mask-wearing was lower in outdoor spaces (42%), consistent with guidelines and lower risk of transmission,[21,22] and very high (>95%) in indoor public spaces with mandatory mask-wearing rules, such as stores and airports. Less appropriately, the proportion wearing a mask on public transit (which was mandatory for the duration of the study) fell between the two, at 79%. Unfortunately, 18% of the latter group were also wearing their mask incorrectly, as were 20% of the subjects who wore a mask outdoors and 11% of those in mandatory mask-use settings. These findings suggest that initiatives on how to wear a mask properly, and reminders in certain public spaces, may be needed.

It is possible that "judicious" incorrect mask-wearing, or wearing a mask incorrectly when farther than 2 metres from anyone else but positioning it properly if coming within 2 metres of another person, may be occurring. We hypothesized that incorrect mask use with the "chin strap", which was most popular in spacious outdoor settings, might be a purposeful choice. In comparison, we hypothesized that the nares exposed might be an inadvertent error (perhaps the top band was not 'pinched' properly, or the mask was too big or worn upside down, or the straps were too long). However, many of the subjects observed to be wearing their mask as a "chin-strap" subsequently had a breach (among outdoor subjects, 63 breaches/100 persons observed).

These findings suggest that if done purposefully, "judicious" mask-wearing doesn't work particularly well.

Despite the high number of breaches among people who wore their mask incorrectly, the high proportion of mask-wearers who wore their mask correctly (and were subsequently unable to breach) diluted the overall number of breaches to a much lower level in the mask-wearing group relative to the non-mask-wearing group. This is contrary to our *a priori* hypothesis, with similar results after adjustment for potential confounders. Of note, in addition to much higher adjusted odds of making a mask-wearing error, the elderly also had a very high adjusted rate of breaches relative to younger persons, which could be secondary to a false sense of security when wearing a mask. The high rate of breaches is particularly worrisome given that they are the highest risk age group.[23,24] This suggests that future interventions that target this group are urgently needed.

Limitations of our study include the setting of two urban North American cities where the study teams were based; our results may not apply to non-North American countries with differing governmental responses to COVID-19 and infection levels. Given enormous social inequalities both within and between countries, where vulnerable/marginalized people live in environments that favor agglomerations, our results may not apply to low- and middle-income countries. In order to include a large and representative sample of the public, as well as avoid the bias introduced by the consent process, we did not consent subjects, and in turn, we had to estimate their characteristics rather than collect this information. Despite our large numbers, the sample size of the elderly age group was small, likely due to the advisory for this group to stay at home.

Certain mask-wearing errors were momentary, and if there was uncertainty, we gave subjects the benefit of the doubt and did not count it as an error; for example, a subject who boarded a bus without a mask, but immediately took a mask from the provided dispenser (and put it on correctly) was not counted as an error. Similarly, we did not count pulling the mask down to eat as a mask error, given that human beings need to eat, and cannot do so wearing a mask correctly. This may have resulted in a slightly conservative estimate of mask-wearing errors. It is possible that the same subject was observed twice, if they returned to the same location during a shift, or even another location that was a study site. Data collectors were encouraged to divide their time equally between morning, afternoon, and evening blocks, but this was not mandatory, making this a convenience sample. Because the study was purely observational, variables that were included in our models were limited to observable characteristics: unmeasured variables could affect the outcome. There were ~3465 new COVID cases in Toronto during our study period (population ~2,700,000) and ~ 4795 in Multnomah county, Portland (population ~650,000), raising the possibility that mask-wearing was higher in the latter city due to a higher infection rate; however, we did not formally explore reasons behind the adjusted differences in mask-wearing between the two cities. This would make an excellent future study. Lastly, public compliance with mask-wearing likely varies over time, in relation to the number of COVID-19 cases. If cases drop to near zero, our results may not apply.

CONCLUSIONS

Compliance with recommendations to wear a mask was relatively high in two North American cities in the summer months of 2020. It was far from perfect, however, particularly on public transit. Elderly persons were the most likely to make mask-wearing errors, and therefore should be targeted by educational mask-wearing campaigns. A mandatory requirement to wear a mask was the greatest predictor of both mask-wearing and correct wear, and was not associated with an inadvertent increase in breaches. These results support mandating mask-use in public settings as an effective public health strategy to prevent the spread of COVID-19.

Competing Interests: Dr Atzema had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. All authors declare that they have no conflicts of interests.

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Contributorship Statement:

Study concept and design: Atzema, Mostarac, Austin, Javidan, Wintraub, Li, Patel, Lee, Latham N, Latham E, Button, Kea.

Acquisition of data: Mostarac, Javidan, Wintraub, Li, Patel, Lee, Latham N, Latham E, Button, Nguyen, Colbert, Chang, Chen, Buerk, Funari, Zimmerman, Somogyi, Brown.

Analysis and interpretation of data: All.

Drafting of the manuscript: Atzema.

Critical revision of the manuscript for important intellectual content: All.

Statistical Analysis: Atzema, Mostarac, Austin, Button, Kea.

Obtained funding: None.

Patient Consent for Publication: Not required.

Role of the Sponsor: *The Heart and Stroke Foundation of Ontario had no involvement in the design or conduct of the study, data management or analysis, or manuscript preparation, review,* *or authorization for submission. This study was supported by ICES, which is funded by an annual grant from the Ontario Ministry of Health and Long-Term Care (MOHLTC). The opinions, results and conclusions reported in this paper are those of the authors and are independent from the funding sources. No endorsement by ICES or the Ontario MOHLTC is intended or should be inferred.*

Data-sharing Statement: De-identified data is available from the authors upon request.

Ethics statement: Ethics approval for the study was obtained from the Research Ethics Board of Sunnybrook Health Sciences Centre (Projet ID: 2019 06/15/2020). The Oregon Health and Science University Internal Review Board considered this a non-human subjects study.

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Figure Legend

Figure 1. The adjusted odds of wearing a mask*

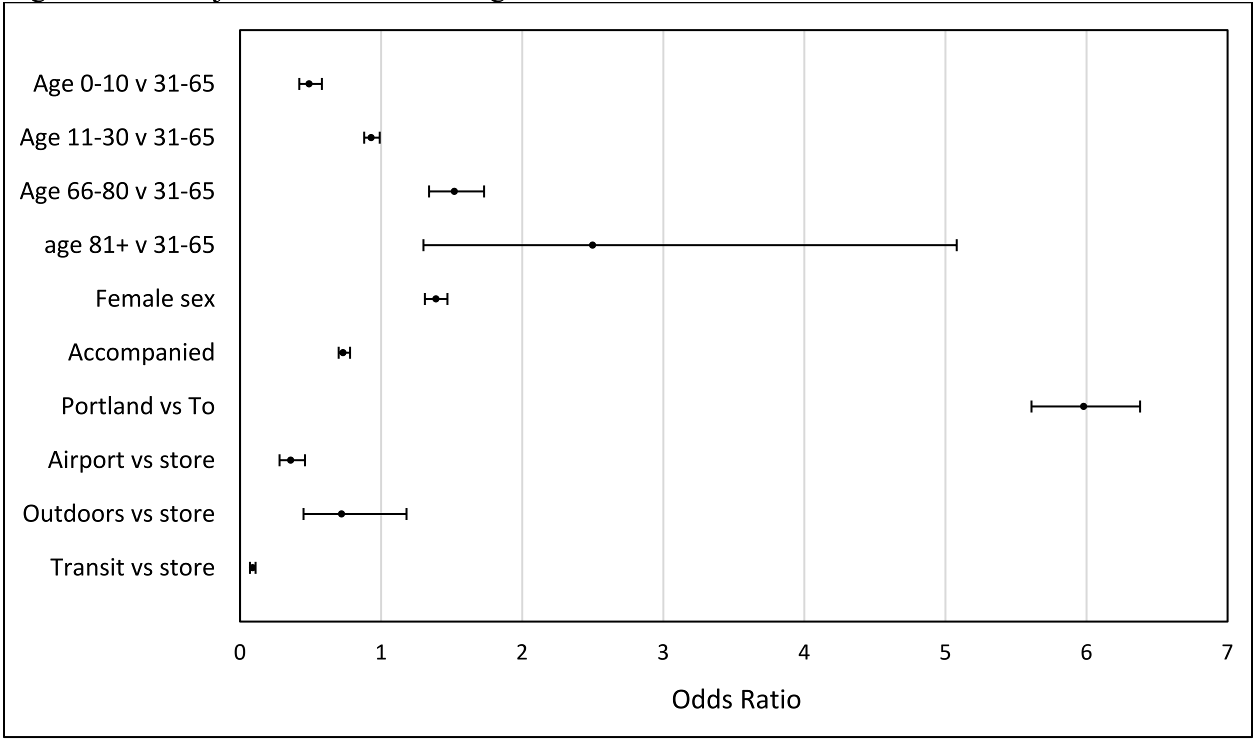
Figure 2. Masked subjects who exhibited incorrect mask-wearing practices by setting (top), and types of errors by setting (bottom)

Figure 3. Among subjects wearing a mask, the adjusted odds of wearing a mask incorrectly

Figure 4. Breaches by venue type (top) and by masking (note that the Mask worn but incorrectly group is a subset of the Mask worn group)

Figure 5. Adjusted rate ratios for breaches

Figure 1. The adjusted odds of wearing a mask*



**Mandatory mask use setting OR is not plotted to improve graph readability: OR 79.2; 95% CI, 47.4-135.*
Interaction between age group and accompanied was not significant (p=0.07)

Figure 2. Masked subjects who exhibited incorrect mask-wearing practices by setting (top), and types of errors by setting (bottom)

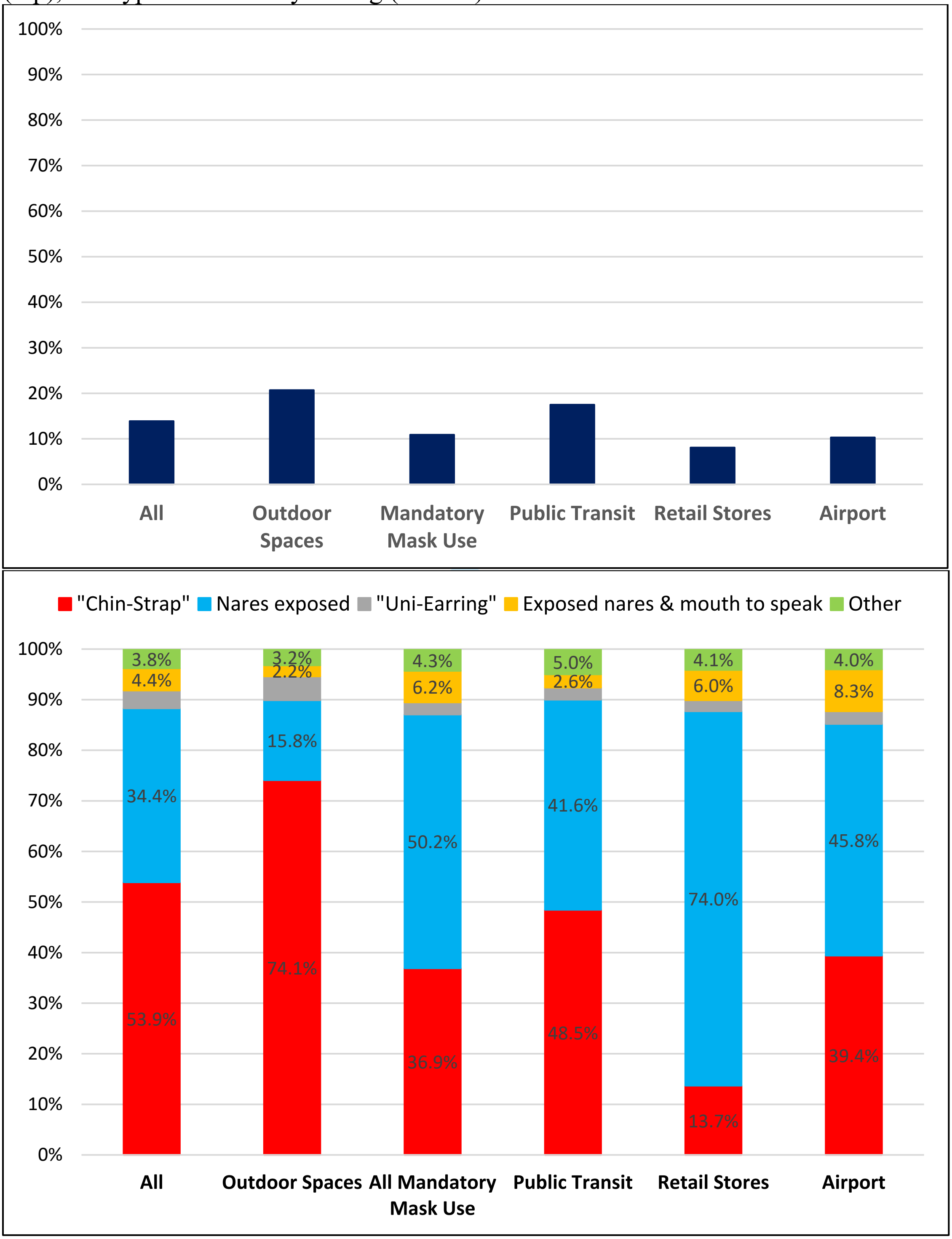
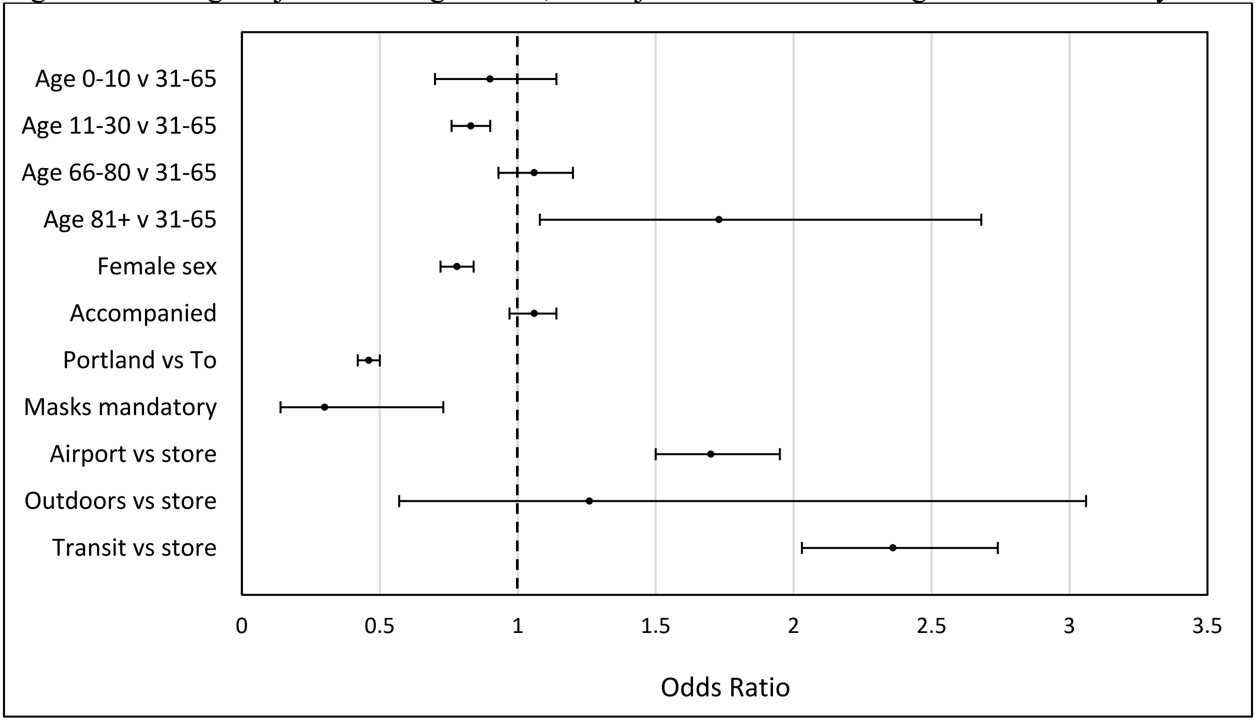


Figure 3. Among subjects wearing a mask, the adjusted odds of wearing a mask incorrectly



Interaction term for age group and accompanied was not significant (p=0.07)

Figure 4. Breaches by venue type (top) and by masking (note that the Mask worn but incorrectly group is a subset of the Mask worn group)

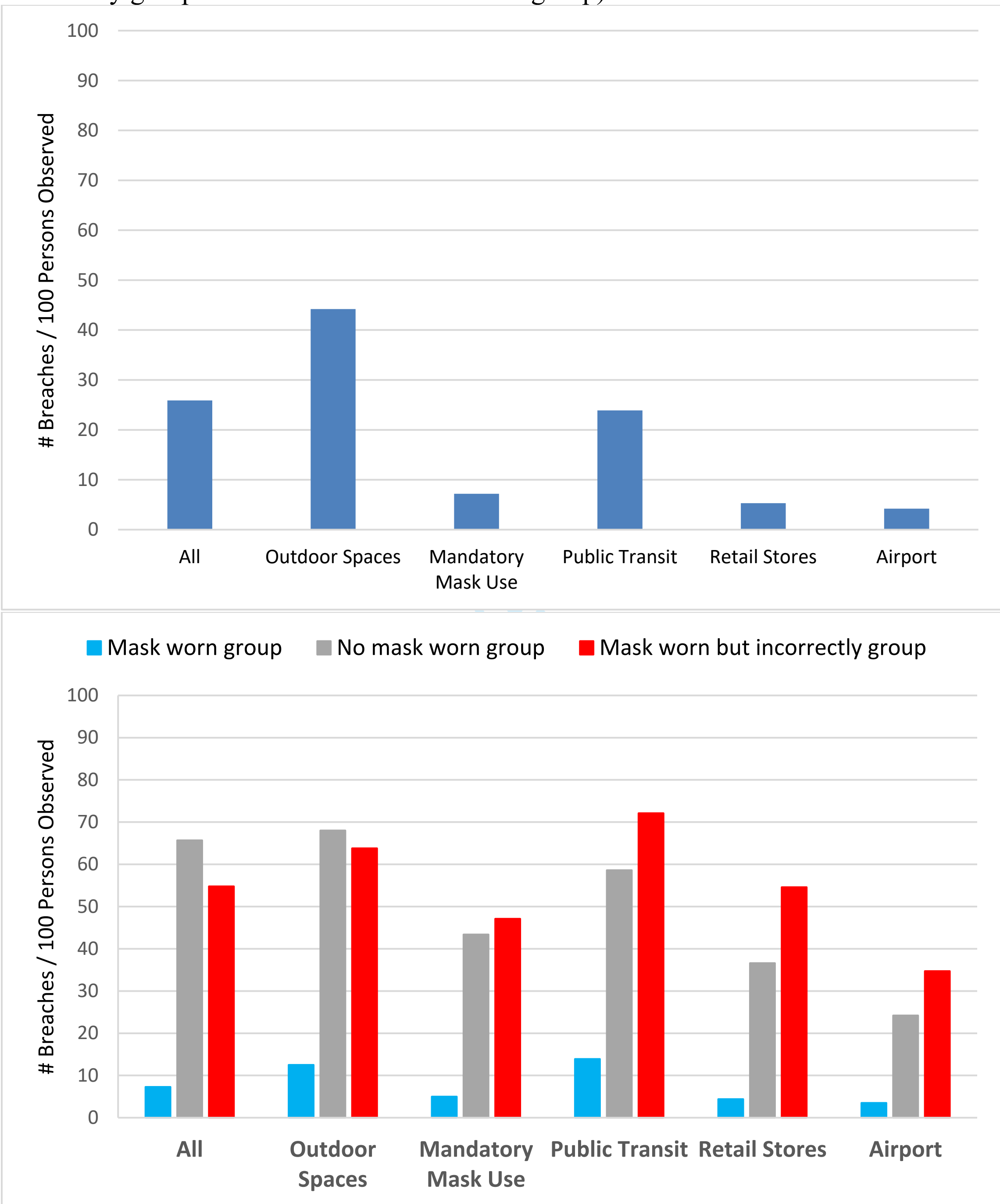
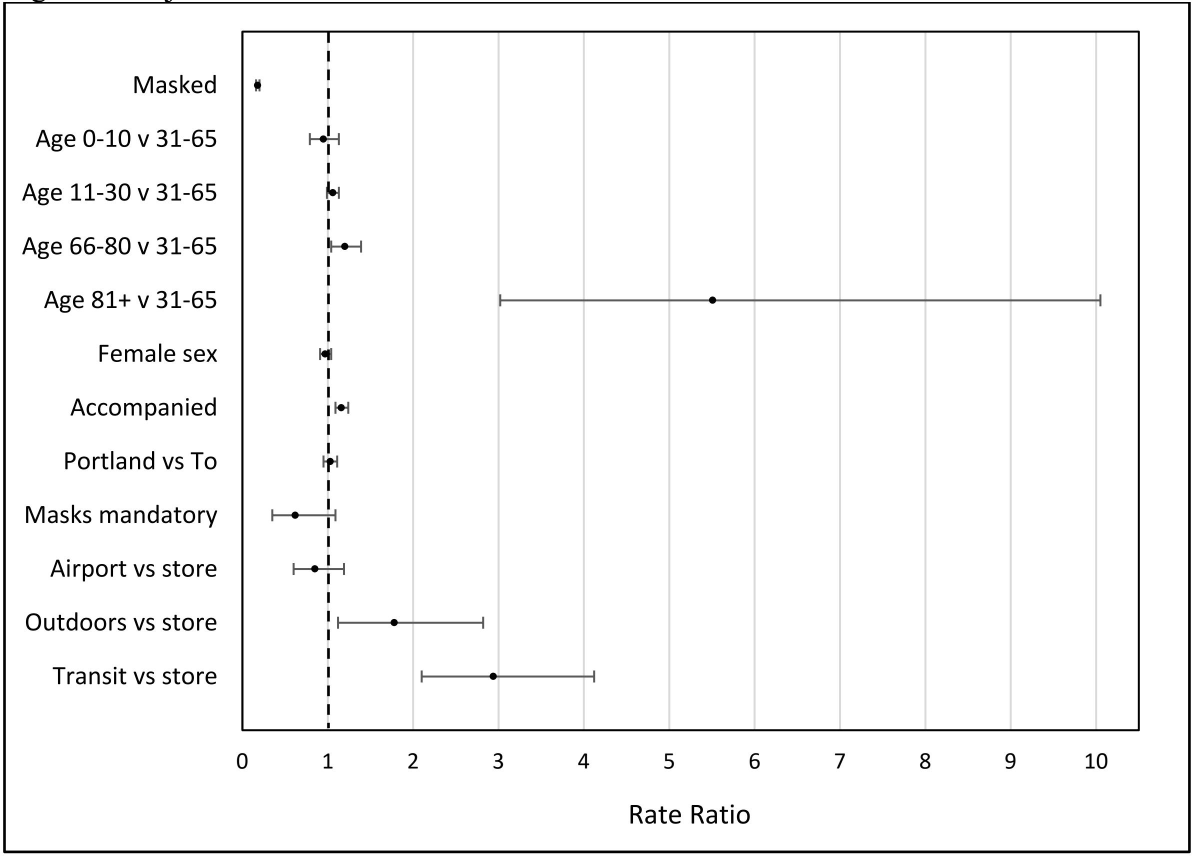


Figure 5. Adjusted rate ratios for breaches



**interaction term for age group and accompanied was not significant (p=0.39)*

Appendix 1 Population demographics for the city of Toronto, ON and Portland, OR and reported COVID-19 outbreaks and case numbers during the study period (June – August 2020) for the city of Toronto, ON and Multnomah County (Portland, OR)

Toronto			Portland		
Demographic	**Persons**		**Demographic**	**Persons**	
Total Population	2 731 571		Total Population	654 741	
Sex			Sex		
Female	1 409 490	(51.6%)	Female	329 990	(50.4%)
Age			Age		
0-9	271 025	(9.9%)	< 5 years	34 701	(5.3%)
10-29	700 325	(25.6%)	< 18 years	116 544	(17.8%)
30-64	1 333 280	(48.8%)	> 65 years	83 807	(12.8%)
65-79	300 300	(11.0%)	Remaining Population (presumably 18-65 years)	454 390	(69.4%)
80+	126 635	(4.6%)			
Ethnic Origin			Ethnic Origin		
European	1 288 855	(40.5%)	White	462 247	(70.6%)
Asian	1 079 290	(33.9%)	Hispanic/Latino	63 510	(9.7%)
Other North American	345 705	(10.9%)	Asian	53 689	(8.2%)
Caribbean	165 735	(5.2%)	Black/African American	37 975	(5.8%)
African	146 870	(4.6%)	Two or More Races	34 701	(5.3%)
Latin/Central/South American	113 815	(3.6%)	American Indian/Alaskan Native	5 238	(0.8%)
North American Aboriginal	35 630	(1.1%)	Native Hawaiian/Other Pacific Islander	3 928	(0.6%)
Oceania	5 790	(0.2%)			
Outbreak Type	**Cases**	**(n=3465)**	**Outbreak Type**	**Cases**	**(n=4795)**
Sporadic *	2928	(84.5%)	Not Specified	4795	(100.0%)
Outbreak Associated †	537	(15.5%)			
Wave 1: March – April 2020			Wave 1: June – August 2020 ‡		

City of Toronto, ON census information obtained from Statistics Canada 2016 Census[25]
Portland, OR census information obtained from United States Census Bureau (2019)[26]
Toronto, ON COVID outbreak and case count information obtained from City of Toronto website[27]
Multnomah County (Portland, OR) COVID case count information obtained from Portland Government website[28]

* Cases in general population not associated with an outbreak (i.e. households or contact with travel related case) † Outbreaks within a defined group or setting (i.e. long term care, workplaces, schools) ‡ https://www.multco.us/novel-coronavirus-covid-19/regional-covid-19-data-dashboard

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	0
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	7
Bias	9	Describe any efforts to address potential sources of bias	7
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8
		(*b*) Describe any methods used to examine subgroups and interactions	8
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	8
		(*e*) Describe any sensitivity analyses	8
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	9
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9, 18
		(b) Indicate number of participants with missing data for each variable of interest	18
Outcome data	15*	Report numbers of outcome events or summary measures	9, 10, 11, 18
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	9, 10, 11, 19, 21, 23
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	9, 10, 11
Discussion			
Key results	18	Summarise key results with reference to study objectives	11, 12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11, 12, 13
Generalisability	21	Discuss the generalisability (external validity) of the study results	13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	0

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.